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Financial Implications of Salt vs. CMA as a Deicing Agent:

Costs & Benefits Estimated by an MTO Expert Group

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Abstract:	A study was undertaken, using a modified Delphi technique, to develop a model for evaluating the costs and benefits of switching from salt to any other deicing chemical, and to apply the model to calcium magnesium acetate (CMA). The additional cost of using CMA rather than salt was significantly greater than the estimated reduction in the five categories of environmental damage considered: vehicle corrosion, bridge deterioration, parking garage deterioration, groundwater contamination, and damage to vegetation and other private property. The most substantial benefit was reduced vehicle corrosion costs. The calculated break-even cost for CMA, i.e. the price at which CMA would have to be purchased in order to balance the environmental benefits, was in the range of $343 to $481/tonne (1985 dollars) depending upon the assumptions made for the discount rate and the amount of the material used.
Comments:	This report is one of a number of reports published by the Ministry dealing with aspects of calcium magnesium acetate. The other reports published to date are MI-108, ME-84-02 and ME-87-16.
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EXECUTIVE SUMMARY

It is salt which historically has been used to keep Ontario roads passable and safe in winter for commercial, commuter, and recreational traffic. Salt is very effective as a deicer and costs relatively little per tonne, but it is known to have damaging effects on vehicles, reinforced concrete highway bridges, parking garages, groundwater, vegetation, and other private property. MTC continues to seek methods of reducing salt usage and to search for affordable alternative deicers which are more benign to the environment. Calcium Magnesium Acetate (CMA) has been identified as one of the most promising alternative deicers.

The decision to use a material as a deicing chemical on highways is based on technical considerations (primarily its effectiveness as a deicer and its effects on the environment), practical considerations (especially handling), and economic considerations (costs and benefits). The Ministry has examined many of the technical and practical aspects of using CMA through the preparation of a state-of-the-art report. Research studies to examine the effect of CMA on vegetation and portland cement concrete have been initiated to address specific Ministry needs not addressed elsewhere. The study reported here was undertaken to examine the economic considerations and had two specific objectives:

i) To develop a model for evaluating the costs and benefits of switching from salt to any other deicing chemical.

ii) To apply the model to determine the financial implications of switching to CMA using the best data currently (1986) available.

Forecasting and estimating was undertaken by an expert group drawn from the Ministry, because some of the data required for a more conventional cost-benefit analysis did not exist. The analysis was done with whatever data were available together with educated "guesstimates" to fill in data that were unavailable. The estimates and assumptions have been documented so that the computations can be revised if better information becomes available in the future.

The analysis was done by taking the difference in costs and benefits between a "salt world", i.e., the present one, and a "CMA world", i.e., with CMA the only deicer used all over Ontario. This approach was taken to avoid consideration of the transition period, since many of the benefits do not accrue unless all jurisdictions switch from salt to CMA.

It was also decided to keep the calculations for provincial highways and for municipal roads ans streets separate, because MTO would be interested in identifying the relative proportion of the costs and benefits accruing to each.

Findings

The most dominant cost was that of CMA, and the most substantial benefit was a reduction in vehicle corrosion costs.

The price of CMA anticipated by the expert group, was so high that the estimated reduction in the five categories of environmental damage considered were not enough to offset material costs. The five categories were vehicle corrosion costs, bridge deterioration costs, parking garage deterioration costs, groundwater contamination costs, and damage to vegetation and other private property.

The range of break-even costs - those at which CMA would have to be available in order just to become warranted on the basis of economics alone - was $343 to $481/tonne depending upon the assumptions made for the discount rate and the rate of growth of material used. By comparison, the cost of producing CMA was estimated by the expert group to be $500 to $550 per tonne, compared with $30 to $40 per tonne for salt. There is little chance that advances in manufacturing technology will bring down the cost of CMA to break even with infrastructure and environmental benefits alone. The likelihood of implementation looked significantly better if the amount of deicer used could be reduced by 1 percent per year over the 20 year period considered in the analysis.

I. INTRODUCTION

It is salt which historically has been used to keep Ontario roads passable and safe in winter for commercial, commuter, and recreational traffic. Salt is very effective as a deicer and costs relatively little per tonne, but it is known to have damaging effects on vehicles, reinforced concrete highway bridges, parking garages, groundwater, vegetation, and other private property (1).

The Ministry report, "Sprinkle Lightly - Salt and Alternatives for Highway De-icing" (2), discussed methods of reducing salt usage and alternatives to the use of salt. It was noted that Calcium Magnesium Acetate (CMA), which was identified in research studies sponsored by the Federal Highway Administration (FHWA) of the United States (3), was one of the most promising alternative deicers.

The decision on whether to use a material as a deicing chemical on highways is based on technical considerations (primarily its effectiveness as a deicer and its effects on the environment), practical considerations (especially handling), and economic considerations (costs and benefits). The Ministry has examined many of the technical and practical aspects of using CMA through the preparation of a state-of-the-art report (4). Research studies to examine the effect of CMA on vegetation and portland cement concrete have been initiated to address specific Ministry needs not the subject of research studies sponsored by other agencies. The study which is the subject of this report, was undertaken to examine the economic considerations and had two specific objectives:

i) To develop a model for evaluating the costs and benefits of switching from salt to any other deicing chemical.

ii) To apply the model to determine the financial implications of switching to CMA using the best data currently (1986) available.

The Need for Cost-Benefit Analysis

A framework is needed in which costs and benefits can be expressed in common units. In financial analysis, this is done by expressing all benefits and costs in terms of their "present value", and by attaching appropriate signs (plus for benefits, minus for costs), a measure of net social benefit can be calculated.

II. DEVELOPMENT AND ASSUMPTIONS OF THE PRESENT APPROACH

The expert group forecasting/estimating approach was taken because some of the data for a more conventional cost-benefit analysis did not exist. The analysis was done with whatever data were available together with educated "guesstimates" to fill in data that were not. Some of the estimates and assumptions were arbitrary. However, these have been documented so that the computations can be revised if better information becomes available in the future. (A fuller account of expert group forecasts/estimates is given in the next chapter).

The possibility that some of the estimates would be in error was accepted, because it was intended that the exercise would be iterative, with dominant components of the costs and benefits being identified after the first iteration. The calculations in this report reflect the results of the final iteration.

The "Salt World" versus the "CMA, or Salt-Free, World"

The analysis was done by taking the difference in costs and benefits between a "salt world", i.e., the present one, and a "CMA world", i.e., with CMA the only deicer used all over Ontario. It was realized that in practice, there would be a transition period since some jurisdictions would inevitably lag others in introducing CMA. This approach avoided the difficulty of estimating the damage that would remain if adjacent geographical areas had different deicers. It is important to note that many of the benefits from CMA do not accrue until all parts of the Province cease using salt.

Interest Rates and Discounting

Society does differentiate between benefits which are realized for immediate consumption and reinvestment, and those which become available at some future date. Accordingly, discount rates are used to convert both benefits and costs into "present values" in the evaluation of projects. Costs and benefits occurring in future years are multiplied by a discount factor $1/(1 + \text{Discount Rate})^n$, where n is the number of years in the future at which the particular benefits or costs occur.

There are two major arguments attendant on the value at which the discount rate is set. The "social opportunity cost" argument says that resources would be wasted if the discount rate used in evaluating public expenditure is less than the return that these funds would yield if invested in the private sector of the economy. This argument by itself, would lead to a relatively high discount rate. An opposing argument, the "social time preference" one, says that individuals are prepared to lend money to governments at much lower rates than those obtained by private entrepreneurs, and that this preference is an expression of society's full evaluation of the relevant factors.

In a report from the planning group of the Treasury Board Secretariat (March 1976), a discount rate of 10%, applied to constant dollars, was recommended, with 5% and 15% being extremes about this rate. The expert group's preference was for the two lower rates, 5% and 10%.

The Time Horizon

The arguments which lead to a compromise such as a twenty year horizon are not precise. If the horizon chosen is short, i.e., less than 5 years, then processes in the evaluation model which change with time will not be captured representatively. An example in the current analysis would be the case in which the requirement for deicer drops steadily by one percent of current values per year. If the horizon chosen is unduly long, i.e., more than 30 years, then in most cases, the extra computational expense is not offset by any improvement in the decision.

Provincial Highways and Ontario Municipalities

The Province of Ontario was taken as the region over which the analysis was to be done. It was realized that there would be some interaction with other provinces, e.g., some of the damage in Ontario would be the result of salt from bordering provinces, but it was thought that the relative magnitude of these interactions would be small.

It was also decided to keep the calculations for provincial highways and municipal roads and streets separate, because MTO was interested in identifying the relative proportion of the costs and benefits accruing to each.

III EXPERT GROUP FORECASTS/ESTIMATES

The expert group forecasting/estimating technique used in this exercise was a modification of the formal technique known as Delphi, after the ancient oracle, supposed by the Greeks to be the centre of the world. This association explains perhaps, why Delphi has come to be understood as "basic", and others such as "structured group meetings", used for the present evaluation of salt versus CMA, as "modifications" to it (see Figure 1). Had the Delphi technique - quite reasonably - been named the "iterative questionnaire survey of experts", that name might not have come to epitomize the entire family of techniques to which it belongs.

The advantages of assigning a task to a group rather than to an individual are clear. There are situations such as the present one, in which no one individual possesses the pool of knowledge, skills, and experience to arrive at all of the estimates required to complete the exercise. The other participants, even when not themselves expert in a particular area under discussion, can help the one who is, by offering comments on the reasoning process, once he has apprised them of the factual premises.

The Classic Delphi Technique

The Delphi technique was developed by Olaf Helmer and Norman Dalkey, senior mathematicians at the Rand Corporation in California. Together with T.J. Gordon of Douglas Aircraft, and under the auspices of Rand, they tested and developed the technique in a series of very careful experiments on group opinion, which they held in 1968.

The Delphi technique is a method of eliciting and refining judgements from individuals in a group of experts, and then by using "statistical" procedures, combining them into the "group judgement". The classic Delphi procedures have three main features:

. Anonymity, i.e., low face-to-face interaction, is intended to reduce specious persuasion through any kind of dominance other than knowledge and logic, of one participant by another. It is achieved by the use of questionnaires, on-line computer responses, or other formal communication channels.

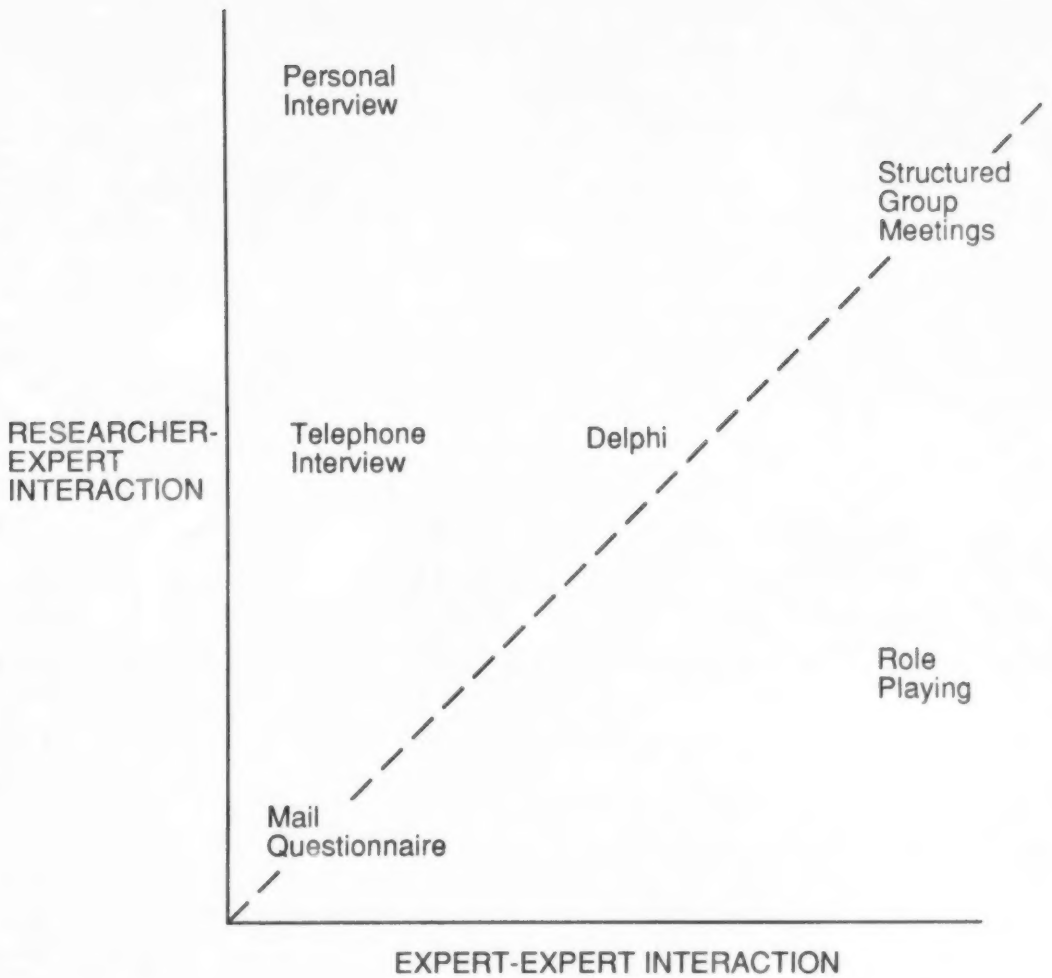

Figure 1/ Delphi and Related Techniques Plotted to Show Interactions (Armstrong Wharton School, Penn.) (Long-Range Forecasting, Wiley, 1978)

- Controlled feedback, i.e., conducting the exercise in a sequence of rounds, and communicating to the participants between each round and the next, a summary of results in the earlier round. This procedure is intended to reduce the relative proportion of "noise" to "meaning" in the exercise.

- "Statistical" procedures for defining the "group judgement". For example, at the feedback stage, participants are given the distribution of responses to the previous questionnaire. Participants whose opinions fall outside the interquartile range, i.e., the interval containing the middle fifty percent of the responses, are asked to reconsider their previous answers and revise them if they want to. Placing the onus of justifying extreme positions (through the researcher) on the respondents who take them, produces either convergence of opinions, or the revelation that different participants are working from different data bases or radically different interpretations of the same data base, a situation which can be resolved before further rounds of the questionnaire are embarked on.

  This procedure can be time-consuming, and in some situations, compromises have to be sought through modifications to the Delphi procedure.

<u>The Expert Group Forecasting and Estimating Technique Used Here</u>

The expert group met for five sessions of about two hours each in December 1985 and in January and March, 1986. At the beginning of the first session, the group was presented with a framework for analysis and partial data required for computations of each of the seven categories of costs and benefits incorporated in the overall financial analysis:

- material costs
- storage and spreading costs
- vehicle corrosion costs
- bridge deterioration costs
- parking garage deterioration costs
- groundwater contamination costs
- damage to vegetation and other private property.

It was anticipated that for a switch from salt to CMA, there would be a net loss in the first two of these seven categories, because of the high cost of CMA and the higher volume of material to be stored and spread, and net savings in the remaining five categories because CMA was assumed to be benign to the environment.

In the course of these five sessions, the expert group started with the first of the seven categories of costs and benefits and worked continuously to the last. By round-the-table discussions and consensus seeking, the group:

1. accepted or replaced with a simpler substitute, the initial framework for analysis of a particular category of costs or benefits;
2. filled in the data required for computations; or
3. instructed the researcher to "dig" for more data from recommended sources.

It was intended that the exercise would be an iterative one, with one of the goals of the first iteration being to identify those categories of benefits or costs which dominate the cost-benefit analysis. One consequence of this intention was that, while data existed to give a more sophisticated treatment to some categories of costs or benefits, i.e., bridge deterioration costs, it was thought that such a treatment was not worth the extra effort.

Membership of the Expert Group

The members of the Expert Group were:

O. Colavincenzo	Manager, Transportation Technology Office, Transportation Technology and Energy Branch
K. Forker	Manager, Equipment Engineering Office, Highway Operations and Maintenance Division.
D. Gardham	Project Engineer, District 6 Maintenance
J. Gruspier	Research Engineer, Materials Office Research and Development Branch
K. Kirchner	Manager, Maintenance Operations Office, Maintenance Branch
D. Laframboise	Manager, Claims and Administration Office, Office of Legal Services

D. Manning	Manager, Materials Office, Research and Development Branch
R. Porter	Director, Maintenance Branch
P. Smith	Director, Research and Development Branch

A. Bacchus of the Research and Development Branch lead the expert group discussions and reported their collective findings.

IV. SEVEN SUB-MODELS AND CALCULATIONS

In this chapter, an outline is given of the seven frameworks for analysis as well as of the calculations that were done to arrive at the final numbers in each of the seven categories of benefits and costs. The explanations given here are meant to complement the individual worksheets and the notes accompanying them.

Material Costs

The basic calculation was:

Cost	= Price	x	Quantity
	or		
Total Cost for a particular year in the 20 year horizon	= Estimated Price in that year in $/tonne	x	Estimated Quantity in that year in tonnes

Once the cost for an individual year was computed, it was discounted to present value by the formula:

Present Value	= Cost in n'th year	x	$1/(1 + \text{Interest})^{n}$ Rate

The sum of twenty individual Present Values was then taken as the overall Present Value.

The above set of calculations was done 24 times - for MTC districts and Ontario municipalities, for 5% and 10% rates of interest, for -1%, 0%, and +1% rates of growth in use of materials for each of the two materials (2 x 2 x 3 x 2 = 24). For readers interested in the computational

complexity of cost-benefit calculations with some sensitivity analysis, another measure is that the "equivalent" calculation:

Present Value of Total Cost for a particular year in the 20 year horizon	=	Estimated Price in that year in $/tonne	x	Estimated Quantity in that year in tonnes	x	$1/(1+1)^n$

was done 24 x 20 = 480 times in order to fill out the sheet on Material Costs.

Storage and Spreading Costs

The calculations for Storage and Spreading Costs were identical in form to those for Material Costs. The quantities of material were the same. Only the four costs of storage and spreading (MTC/Municipalities and salt/CMA) were different.

Vehicle Corrosion Costs

The basic equation developed by the expert group was:

Annual Savings in Corrosion Costs with CMA	=	Number of new vehicles/yr	x	Cost of Corrosion Protection per vehicle	x	Component of Corrosion Cost Attributable to salt = 0.5
	+	Total Population of vehicles	x	(Decreased (Financing (Cost/yr	-	Increased) Maintenance) Cost/yr)

The first part of the equation sets the cost of corrosion attributable to salt as a fraction of the full protection cost payable at the beginning of the vehicle's life. It was reasoned that in the few cases in which full corrosion protection was not applied to the vehicle at the beginning of its life, equivalent costs would have to be met during its lifetime.

The decreased financing costs in the second part of the equation results from the extra life anticipated for a vehicle in the CMA world and therefore, the fewer purchases of cars in the long run. The sixty-year horizon used in the calculations for cars, for example (see worksheets), is for computational convenience; 60 is the least common multiple of 10 and 12. No prediction of longevity for Ontario vehicle owners is intended.

The increased maintenance costs are also the result of longer life in the CMA world. The cost of extra mechanical maintenance on the vehicle for the years of extra life are spread over the entire life to get an equivalent annual amount.

Bridge Deterioration Costs

In the context of the present exercise, calculations using averages were adequate. It was intended from the beginning, that the whole exercise would be iterative, with a decision to be made after the first iteration on whether more effort was warranted for a particular component, based on its relative contribution to the final result. Since bridge deterioration costs were calculated to be only approximately 10 percent of vehicle corrosion costs, it was decided that a more sophisticated analysis was unnecessary.

Parking Garage Deterioration Costs

The point about using averages, and the degree of sophistication of the analysis made in the discussion on bridges (above) holds here.

Groundwater Contamination Costs and
Damage to Vegetation and Other Private Property

The reasoning and the calculations are shown on the worksheets. No account has been taken in the calculations of the additional, indirect costs to MTC or municipalities of litigation, environmental hearings, and embarrassment due to salt damage.

V. SUMMARY AND CONCLUSIONS

The summaries on pages A-1 and A-2 of Appendix A combine the seven categories of benefits and costs into an overall financial analysis. It is clear that the most dominant components of the costs were:

1) The cost of CMA, arising from the very high price and the large amount used, relative to the price and amount of salt.
2) The vehicle corrosion costs.

The price of CMA, anticipated by the expert group, was so high that the reduction in the five categories of environmental damage, namely Vehicle Corrosion Costs, Bridge Deterioration Costs, Parking Garage Deterioration Costs, Groundwater Contamination Costs, and Damage to Vegetation and other Private Property (high as the first three were) were not enough to offset material costs.

Higher rates of discount reduce future streams of costs and benefits, relative to lower rates. This is why the net present values are less in the Summary Sheet for the 10 percent rate than for the 5 percent discount rate. However, this relationship can be distorted when net effects (in this case, the TOTAL PRESENT VALUE in Appendix A) are calculated by adding and subtracting large numbers, as occurs for the -1 percent growth rate in material use.

The likelihood of implementation looked significantly better, the smaller the amount of deicer predicted; the net loss in dollars was smallest when the weight of material used was predicted to decline by 1% per year.

Break-Even Analysis - Tables on Page A-3

The break-even costs under different scenarios (rate of growth in use of material and discount rate) were those at which CMA would have to be available in order to become just feasible as an alternative to salt - if the decision were to be made on the basis of cost-benefit analysis. At higher rates of consumption, the price had to be driven down lower to break even.

For all scenarios taken together, the range of break-even costs was $343 to $481 per tonne. This then becomes a basis for developing budgetary implications and implementation strategies.

Per-Capita Effect

The average taxpayer is sensitive to the extra tax burden which would result from increased municipal and provincial spending on CMA and to the direct benefit of reduced corrosion to his or her car. The taxpayer is

less sensitive to other benefits such as those to bridge decks, parking garages, groundwater and vegetation. It is interesting to put the burden on the individual in perspective.

If Ontario were to switch completely from salt to CMA, the total additional cost to the Province and to municipalities would be just over $1 billion per year. If this extra expense were to be spread over the adult (age 20 to 65) population of 5.3 million, the per capita cost would be just under $190 per year.

The savings in corrosion damage to cars resulting from a switch from salt to CMA will be about $650 million per year. If this saving were to be spread over the car population of 4.8 million, the saving per car would be about $135 per year.

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4. Pianca, F., "Evaluation of CMA as an Alternative De-icer", MTC, 1984.

APPENDIX A

- Summary Sheet (5% Discount Rate)
- Summary Sheet (10% Discount Rate)
- Break-Even Costs (5% and 10% Discount Rates)

SUMMARY SHEET (5% DISCOUNT RATE)

COST ITEM	NET PRESENT VALUE OF SAVINGS FROM SWITCH TO CMA (1985 DOLLARS x 10^6)								
	MTO			MUNICIPALITIES			OVERALL		
Materials Costs -given different rates of growth in use of material	-1%	0%	+1%	-1%	0%	+1%	-1%	0%	+1%
	-5552	-6094	-6636	-7097	-7790	-8483	-12649	-13884	-15119
Storage and Spreading Costs -given different rates of growth in use of material	-106	-116	-127	-136	-149	-162	-242	-265	-299
Vehicle Corrosion Costs								8437	
Bridge Deterioration Costs		328			572			900	
Parking Garage Deterioration Costs								1795	
Groundwater Contamination Costs		23			51			74	
Damage to Vegetation and other Private Property		11			24			35	
TOTAL PRESENT VALUE (in 1985 dollars x 10^6)							-1650	-2908	-4177

NOTES:

Not modelled
. Ripple effect on the Ontario economy of a switch to CMA which would be substantial.
. Internal cost to MTC of litigation, environmental hearings, and embarrassment due to salt damage.
. Nuisances which CMA would not eliminate - stains on boots, trousers, etc.

SUMMARY SHEET (10% DISCOUNT RATE)

COST ITEM	NET PRESENT VALUE OF SAVINGS FROM SWITCH TO CMA (1985 DOLLARS x 10^6)								
	MTO			MUNICIPALITIES			OVERALL		
Materials Costs -given different rates of growth in use of material	-1%	0%	+1%	-1%	0%	+1%	-1%	0%	+1%
	-3842	-4163	-4471	-4933	-5322	-5698	-8775	-9485	-10169
Storage and Spreading Costs -given different rates of growth in use of material	-73	-79	-85	-94	-101	-111	-167	-180	-196
Vehicle Corrosion Costs								5117	
Bridge Deterioration Costs		225			390			615	
Parking Garage Deterioration Costs								1226	
Groundwater Contamination Costs		14			32			46	
Damage to Vegetation and other Private Property		8			17			25	
TOTAL PRESENT VALUE (in 1985 dollars x 10^6)							-1913	-2636	-3336

NOTES:

Not modelled
. Ripple effect on the Ontario economy of a switch to CMA which would be substantial.
. Internal cost to MTC of litigation, environmental hearings, and embarrassment due to salt damage.
. Nuisances which CMA would not eliminate - stains on boots, trousers, etc.

BREAK-EVEN ANALYSIS

The following tables give the cost, under various assumptions, to which CMA would have to drop to make it a viable alternative to salt, i.e., to make Net Present Value of (Costs - Benefits) = 0

AT 5% DISCOUNT RATE

Rate of growth in use of material	-1%	0%	+1%
Price to MTO in $/tonne	437	399	368
Price to Municipalities in $/tonne	481	440	405

AT 10% DISCOUNT RATE

Rate of growth in use of material	-1%	0%	+1%
Price to MTO in $/tonne	395	367	343
Price to Municipalities in $/tonne	436	404	378

APPENDIX B

Worksheets and Notes for Seven Categories of Benefits and Costs:

- Material Costs
- Storage and Spreading Costs
- Vehicle Corrosion Costs
- Bridge Deterioration Costs
- Parking Garage Deterioration Costs
- Groundwater Contamination Costs
- Damage to Vegetation and other Private Property

NOTES ON TABLE OF COMPUTATIONS FOR MATERIAL COSTS

1. Maintenance Branch: Calculated from tonnages and costs for each MTC district.

2. Average of costs, delivered, to eight municipalities in the Kingston, Huntsville, Sudbury, and Thunder Bay areas.

3. The price of salt, in constant 1985 dollars, is expected by the expert group to remain unchanged. One factor underlying this speculation was the decision in the work reported here, to consider a "pure salt world" and a "pure CMA world" in turn; there would therefore, be no interaction effects of the supplies and demands for the two materials.

4. Intelligence on the entire Ontario market amassed by Sifto Salt/ Domtar. Their estimate of 600,000 tonnes for MTO matches our own numbers closely.

5. The growth would be the result of changes in either the total "kilometrage" of hard-surfaced (concrete, asphalt-on-concrete, or high-class bituminous) provincial roads or the application rate.

6. The expert group reasoned that, given what we know about recent small scale manufacturing experience in North America, this was the best assumption for our computations. It was intended, in any case, to compute the "break-even" price per tonne of CMA, i.e., the price at which CMA would have to be available to make it feasible.

7. A factor of 1.1 was applied to the MTO district price, as opposed to the factor of 1.2 which emerged in the case of salt, as an arbitrary allowance for the relatively greater number of CMA plants anticipated in Ontario, bringing transportation costs down.

8. The value accepted by the expert group and based on information from small trials around North America.

MATERIAL COSTS

	MTO DISTRICTS			ONTARIO MUNICIPALITIES		
Salt						
Current Price in $/tonne		35			42	
Likely Price in 5,10,20 years (1985 dollars)		35	35	42	42	42
Current Quantity (000)		600			700	
Given, for sensitivity analysis, rates of growth of -1%, 0%, +1% of current requirements per year the quantity in -	-1%	0%	+1%	-1%	0%	+1%
5 years	570	600	630	665	700	735
10 years	540	600	660	630	700	770
20 years	480	600	720	560	700	840
Present Value of these costs (in 1985 dollars x 10^6)						
Discounted: 5%, 20 years		482	285	334	366	399
Discounted: 10%, 20 years	165	179	192	232	250	268
CMA						
Current Price in $/tonne		500			550	
Likely Price in 5,10,20 years (1985 dollars)	500	500	500	550	550	550
Weight of CMA "equivalent" in deicing power to current quantity of salt, in tonnes (000) = 1.7 x current quantity of salt		1020			1190	
Given, for sensitivity analysis, rates of growth of -1%, 0%, +1% of current requirements per year, the quantity in -	-1%	0%	+1%	-1%	0%	+1%
5 years	969	1020	1071	1131	1190	1250
10 years	918	1020	1122	1071	1190	1309
20 years	816	1020	1224	952	1190	1428
Present Value of these costs (in 1985 dollars x 10^6)						
Discounted: 5%, 20 years	5790	6356	6921	7431	8156	8882
Discounted: 10%, 20 years	4007	4342	4663	5165	5572	5966
Extra Cost of CMA						
Discounted: 5%, 20 years	5552	6094	6636	7097	7790	8483
Discounted: 10%, 20 years	3842	4163	4471	4933	5322	5698

NOTES ON TABLE OF COMPUTATIONS FOR STORAGE AND SPREADING COSTS

1. Maintenance Branch: Sample of three districts.

2. Average of costs in 5 municipalities in the Kingston, Huntsville, and Sudbury areas.

3. The bulk density of an early form of CMA was estimated at 40 lb/ft^3. The bulk density of salt is about 85 lb/ft^3. These numbers, by themselves, would lead to a value of 2.1 for this adjustment ratio. It was thought though, that efficiencies would be derived from several sources:
   - Larger spreaders would be introduced.
   - Greater application rates would lead to a lower haulage component of spreading costs.
   - The larger number of smaller plants anticipated in a CMA world would reduce the amounts that would have to be stockpiled.

   The ratio was reduced, in recognition of these factors, to an arbitrary level of 1.5.

STORAGE AND SPREADING COSTS

	MTO DISTRICTS			ONTARIO MUNICIPALITIES		
Salt						
Current Quantity in tonnes (000) (See section on Material Costs)		600			700	
Likely Quantity in -	-1%	0%	+1%	-1%	0%	+1%
5 years	570	600	630	665	700	735
10 years	540	600	660	630	700	770
20 years	480	600	720	560	700	840
Cost of Storage & Spreading in $/tonne of salt - all proportions of sand/salt mix		10			11	
Present Value of these costs (in 1985 dollars x 10^6)						
Discounted: 5%, 20 years	68	75	81	87	96	105
Discounted: 10%, 20 years	47	51	55	61	66	70
CMA						
Weight of CMA "equivalent" in deicing power to current quantity of salt, in tonnes (000) (See section on Material Costs)		1020			1190	
Likely Quantity in -	-1%	0%	+1%	-1%	0%	+1%
5 years	969	1020	1071	1131	1190	1250
10 years	918	1020	1122	1071	1190	1309
20 years	816	1020	1224	952	1190	1428
Cost of Storage & Spreading in $/tonne = 1.5 x $/tonne for storing and spreading salt		15			16.5	
Present Value of these costs						
Discounted: 5%, 20 years	174	191	208	223	245	267
Discounted: 10%, 20 years	120	130	140	155	167	181
Extra Cost of CMA						
Discounted: 5%, 20 years	106	116	127	136	149	162
Discounted: 10%, 20 years	73	79	85	94	101	111

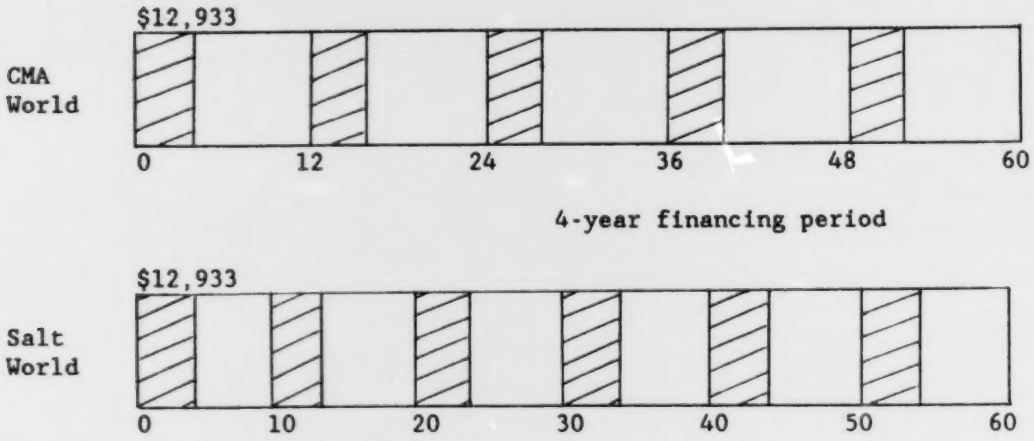
VEHICLE CORROSION COSTS

Equation

Annual Savings in Corrosion Costs with CMA	= Number of new vehicles/yr	x Cost of Corrosion Protection per vehicle	x Component of Corrosion Cost Attributable to salt = 0.5
	+ Total Populaton of vehicles	x (Decreased (Financing (Cost/yr	- Increased) Maintenance) Cost/yr)

For Cars			
Annual Savings in Corrosion Costs with CMA	$= 480 \times 10^3$	x $290 ($206 (5%))	x 0.5
	$+ 4812 \times 10^3$	x ($188 (10%))	- 80)
	$- \$676 \times 10^6$	using 5% as discount rate	
or	$\$590 \times 10^6$	using 10% as discount rate	
For Trucks			
Annual Savings in Corrosion Costs with CMA	$= 4.6 \times 10^3$	x $620 ($2 $\times 10^3$ (5%))	x 0.5
	$+ 46 \times 10^3$	x ($2.2 $\times 10^3$ (10%))	- $2.0 $\times 10^3$)
	$- 1.4 \times 10^6$	using 5% as discount rate	
or	10.6×10^6	using 10% as discount rate	
For Transit Buses			
Annual Savings in Corrosion Costs with CMA	$= 0.43 \times 10^3$	x $400 ($1.8 $\times 10^3$ (5%))	x 0.5
	$+ 4.3 \times 10^3$	x ($1.5 $\times 10^3$ (10%))	- $2.2 $\times 10^3$)
	NEGATIVE		
School Buses			
Annual Savings in Corrosion Costs with CMA	$= 0.84 \times 10^3$	x $400 ($1.5 $\times 10^3$ (5%))	x 0.5
	$+ 8.4 \times 10^3$	x ($1.3 $\times 10^3$ (10%))	- $2.1 $\times 10^3$)
	NEGATIVE		
Inter-City Coaches			
Annual Savings in Corrosion Costs with CMA	$= 0.05 \times 10^3$	x $400 ($2.6 $\times 10^3$ (5%))	x 0.5
	$+ 0.5 \times 10^3$	x ($2.2 $\times 10^3$ (10%))	- $8.2 $\times 10^3$)
	NEGATIVE		
These negative results may imply that buses are kept in service too long.			
Total Annual Savings for Cars and Trucks			
	$- \$677 \times 10^6$	using 5% as discount rate	
	$- \$601 \times 10^6$	using 10% as discount rate	
Present Value of Savings			
Discounted at 5% over 20 years		$- \$8437 \times 10^6$	
Discounted at 10% over 20 years		$- \$5117 \times 10^6$	

DECREASED FINANCING COSTS IN THE CMA WORLD - CARS



CMA WORLD

1. Present Value of a stream of expenditures of $12,933 at years 1, 13, 25, 37, 49 -

   5%: $12933 (0.95238 + 0.53032 + 0.29530 + 0.16559 + 0.09202)
   - $12933 x 2.03561 - $26,327

   10%: $12933 (0.90909 + 0.28966 + 0.09230 + 0.03018 + 0.00956)
   - $12933 x 1.33079 - $17,211.

2. Spread this consolidated Present Value evenly over 60 years, using the Capital Recovery Factor:

   5%: $26327 x 0.05283 - $1391
   10%: $17211 x 0.10033 - $1727

SALT WORLD

1. Present Value of a stream of expenditures of $12,933 at years 1, 11, 21, 31, 41, 51 -

   5%: $12933 (0.95238 + 0.58468 + 0.35894 + 0.22136 + 0.1359 + 0.08343)
   - $12933 x 2.33669 - $30220

   10%: $12933 (0.90909 + 0.35049 + 0.13513 + 0.05296 + 0.02042 + 0.00787)
   - $12933 x 1.47596 - $19089

2. Spread this consolidated Present Value evenly over 60 years, using the Capital Recovery Factor

   5%: $30220 x 0.05283 - $1597
   10%: $19089 x 0.10033 - $1915.

DECREASED FINANCING COST IN CMA WORLD - $206/yr at 5% discount rate
$188/yr at 10% discount rate.

NOTES ON INVENTORY OF DATA FOR VEHICLE CORROSION COST CALCULATIONS

1. Overall numbers of "fit and active" cars, commercial vehicles and buses come from the Licensing and Control Branch of MTO. Numbers given are those on record at December 1984.

2. The number of "true" trucks, i.e., straight trucks and tractor/trailers, is given as 46000 by the Ontario Commercial Vehicle Survey published by the Policy Planning Branch. The total number of "fit and active" commercial vehicles is 858000. The difference, 812000 vehicles, is the number therefore, of small vans, station wagons, etc.; more like cars than trucks.

3. The number of "fit and active" school buses in Ontario is 8408 (Marg Mooney, Licensing Administration Office, Licensing and Control Branch, MTO). The number of transit buses is given as 4300 by the Canadian Urban Transit Association handbook. The number of inter-city buses in Ontario is around 500 (M. Blurton, Policy Planning Branch).

4. The expert group agreed on 10% of current stock as a reasonable estimate of the number of new vehicles per year.

5. These numbers were obtained in estimates from Ziebart and two other companies in the rust-protection business, randomly chosen.

6. The 50% figure was agreed upon by the expert group.

7. The additional mechanical maintenance in the extra years of life in the CMA world is "spread over" the lifetime itself to get an equivalent annual increase.

8. Mechanical maintenance data supplied to the Ontario Motor League in a survey on costs by model year done in 1984.

9. Data from Transport Canada Report TP921, Operating Costs of Trucks in Canada, 1984.

10. Canadian Urban Transit Association Handbook/Work in Progress by J. Turner, Transportation Technology and Energy Branch.

11. & 12. Calculations with data supplied by large company with fleet of both school buses and inter-city buses. Company did not want its name or detailed data published.

13. N. Clarke, President of the Motor Vehicle Manufacturers Association.

14. J. Billing, Transportation Technology and Energy Branch:
Tractor - 7 years; Trailer - 14 years, take 10.

NOTES ON INVENTORY OF DATA FOR VEHICLE CORROSION COST CALCULATIONS (continued)

15., 16. & 17. Information from 5 large bus companies around Ontario.

18. Includes manufacturer's invoice, dealer's markup, standard equipment and options, freight, preparation delivery and inspection, and Ontario sales tax (Statistics Canada/Motor Vehicle Manufacturing Association).

19. J. Billing, Transportation Technology and Energy Branch.

20., 21. & 22. Information from 5 large bus companies around Ontario.

23. True, typically, even for larger vehicles like buses and trucks - Mr. Chatoff, Greycoach Ltd.

INVENTORY OF DATA FOR VEHICLE CORROSION COST CALCULATIONS

	"CARS"	TRUCKS	TRANSIT BUSES	SCHOOL BUSES	INTER-CITY BUSES
Total population of "fit and active" vehicles (000) (1)	4000 + 812 (2) (commercial veh. more like cars than trucks)	46 (2)	4.3 (3)	8.4 (3)	0.5 (3)
Number of new vehicles/year (as opposed to net number)(000) (4)	480	4.6	0.43	0.84	1.18
Cost of corrosion protection (average of Ziebert and two other picked at random) Trucks and buses - $10/lineal ft. (5)	$290	$620	$400	$400	$400
Component of corrosion cost attributable to salt (6)	0.5	0.5	0.5	0.5	0.5
Increased maintenance costs/year in extra life in CMA world (7)	(8) $\frac{\$480 \times 2}{12} = \$80/yr$	(9) $\frac{\$12 \times 10^3 \times 2}{12} = \$2 \times 10^3$	(10) $\frac{\$13.3 \times 10^3 \times 3}{18} = \$2.2 \times 10^3$	(11) $\frac{\$10.6 \times 10^3 \times 2}{10} = \$2.1 \times 10^3$	(12) $\frac{\$49 \times 10^3 \times 3}{18} = \$8.2 \times 10^3$
FOR CALCULATION OF DECREASED FINANCING COST/YR:					
Lifetime of vehicle in salt world in yr.	10 (13)	10 (14)	15 (15)	8 (16)	15 (17)
Lifetime of vehicle in CMA world in yr. (Add 20% - Expert Group)	12	12	18	10	18
Average price in $(000)	12.9 (18)	150 (19)	180 (20)	60 (21)	250 (22)
Time horizon - picked to minimize salvage considerations - yr.	60	60	60	40	60
Financing period - yr. (23)	4	4	4	4	4

NOTES ON TABLE OF COMPUTATIONS FOR BRIDGE DETERIORATION COSTS

1. Annual Maintenance on a bridge costs about 3% of the (initial) value of the bridge. Compare with the case of parking garages for which, because of inferior construction standards, the corresponding figure is 6% (DM).

2. Half of the maintenance costs are assumed to be the result of salt usage - scaling of concrete and corrosion of structural steel and embedded reinforcement.

3. & 5. MTO bridge inventory/DM.

4. Cost of bridge/(m^2 of deck) - \$947 (1985 figure, from the Structural Office, off contract documents).

   Average area of MTO bridges - 8321 ft^2 (bridge inventory/DM)$_2$
   Value of MTO bridge - (8321 ft^2)$_3$ x 0.0929)m^2 x \$947/m^2
   - \$732 x 10^3.

6. Cost of bridge/(m^2 of deck) - \$947 -assume MTO figure
   Average area of municipal bridge - 3306 ft^2 (bridge inventory: estimated by taking every$_2$tenth bridge)
   Value of municipal bridge - (3306 ft^2)$_3$ x 0.0929)m^2 x \$947/m^2
   - \$291 x 10^3

BRIDGE DETERIORATION COSTS (CURRENT POPULATION)

Equation:

Annual Savings in Bridge Corrosion Cost = _____ Bridges x $_____ Value/Bridge x 0.03[1] Maintenance Cost Factor x 0.5[2] Component of Maintenance Costs Attributable to Salt Damage

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For MTO Bridges

Annual Savings = 2400[3] x $732[4] x 10^3 x 0.03 x 0.5
= $26352 x 10^3

Present Value of these savings, in 1985 dollars:

Discounted at 5% over 20 years = $328 x 10^6
Discounted at 10% over 20 years = $225 x 10^6

For Municipal Bridges

Annual Savings = 10500[5] x $291[6] x 10^3 x 0.03 x 0.5
= $45833 x 10^3

Present Value of these savings, in 1985 dollars:

Discounted at 5% over 20 years = $572 x 10^6
Discounted at 10% over 20 years = $390 x 10^6

NOTES ON TABLE OF COMPUTATIONS FOR PARKING GARAGE DETERIORATION COSTS

1. Annual Maintenance on a parking spot costs about 6% of the (initial) value of the spot. Compare with the case of bridges for which, because of superior construction standards, the corresponding figure is 3% (DM).

2. This corrosion component is half as much again as that for bridges, because of the difference in construction standards.

3. Same, reliable source as for number of residential spaces. But this source did not want to be named.

PARKING GARAGE DETERIORATION COSTS (CURRENT POPULATION)

Equation:

Annual Savings in Parking Garage Corrosion Costs	=	_____ "Reinforced Concrete Spaces"	x	$_____ Value/ Space	x	0.06[1] Maintenance Cost Factor	x	0.75[2] Corrosion Component of Maintenance Costs

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For Residential Spaces

Annual Savings $= 224 \times 10^3 \times 7500^{(3)} \times 0.06 \times 0.75$
$= \$76 \times 10^6$

For Commercial Spaces

Annual Savings $= 200 \times 10^3 \times \$7500 \times 0.06 \times 0.75$
$= \$68 \times 10^6$

Total Savings $= \$144 \times 10^6$ per year.

PRESENT VALUE OF THESE SAVINGS, IN 1985 DOLLARS:

Discounted at 5% over 20 years $= \$1795 \times 10^6$
Discounted at 10% over 20 years $= \$1226 \times 10^6$

Number of Commercial Spaces - Two Approaches

1. _____: 400×10^3 "reinforced concrete spaces" in all
   _____: 224×10^3 residential spaces (source did not wish to be named)
   So 176×10^3 commercial spaces.

2. Estimated 31×10^3 reinforced concrete spaces in City of Toronto (population 647×10^3). Total population of 24 Ontario population centres with greater than 75,000 people each - 5001×10^3. Factoring up we get 240×10^3 commercial spaces.

3. Take 200×10^3 spaces.

GROUNDWATER CONTAMINATION COSTS

Reference: Don Laframboise/Don Sawyer
Claims and Administration Office

Claims against MTO

(a) Replacement or rehabilitation of wells
(1985 dollars x 10^3)
100 claims at $5000/yr — 500

(b) Claims for personal health in addition to claims for wells
(1985 dollars x 10^3)
4 claims at $15000/yr — 60

(c) Claims for contamination due to salt stockpiles in MTO patrol yards
(1985 dollars x 10^3)
2 claims at $150,000/yr — 300

860 x 10^3

Assume growth of 12 1/2% of current levels/year in a salt world, complete elimination in a CMA world:

Present Value of these savings, in 1985 dollars
Discounted at 5% over 20 years - $23 x 10^6
Discounted at 10% over 20 years - $14 x 10^6

Claims against Municipalities

Apply ratio of hard/good surface road "kilometrage":
km of MTO hard/good surface road - 17,431
km of Municipal hard/good surface road - 38,785

Required ratio is 1:2.225

We get:
Present Value of savings, in 1985 dollars
Discounted at 5% over 20 years - $51 x 10^6
Discounted at 10% over 20 years - $32 x 10^6

NOTES ON TABLE OF COMPUTATIONS FOR DAMAGE TO VEGETATION AND OTHER PRIVATE PROPERTY

1. Orchards adjacent to Ontario provincial highways can be represented by a rectangle whose total length is 205 km. This column in the table on the opposite page gives the breakdown of this total length by individual crops. Source: Letter from H. Blaine, Maintenance Management, MTO (1984) to J. Gruspier, Research and Development Branch, MTO.

2. The width of the affected rectangle is 30 m (JG).

3. Published farm production data (1983) from the Ministry of Agriculture and Food.

4. Percentages arrived at by the expert group.

DAMAGE TO VEGETATION AND OTHER PRIVATE PROPERTY

Claims Against MTO

Fruit	Highway(1) Frontage km	Affected(2) Area km^2	Full (3) Value $\$/km^2/yr$ (000)	% Damage(4)	$ Loss/Yr (000)
Apple	119	3.57	357	30%	382
Peach	17	0.51	513	60%	157
Mixed (apple and other or peach and other)	49	1.47	369 For want of precise proportions a simple arithmetic average is taken	45%	244
Nursery (shrubs)	3	0.09	?	45%	---
Other (grapes or plums or pears)	17	0.51	325 (av. - 349) (257) (and 370)	60%	99
TOTAL					882

NOTE: It is realized that damage occurs, in a salt world, to lawns, gardens, aluminum siding, boats, etc., but data on these items are not readily available.

Present Value of these savings, in 1985 dollars
Discounted at 5% over 20 years - $\$11 \times 10^6$
Discounted at 10% over 20 years - $\$ 8 \times 10^6$

Claims Against Municipalities

Applying ratio of 1:2.225 (see Section on Groundwater), we get:
Present Value of Savings, in 1985 Dollars
Discounted at 5% over 20 years - $\$24 \times 10^6$
Discounted at 10% over 20 years - $\$17 \times 10^6$